

## HEAT-RESISTANT PLASTIC TUBE

### Cross-Reference to Related Application

This application is a Continuation of International Patent  
5 Application Serial No. PCT/JP02/07365 filed July 19, 2002, which  
was published in Japanese on January 30, 2003 as WO 03/008850  
A1.

### Technical Field

10 This invention relates to a heat resistant tube that can  
be thermally bent at a temperature of the environment in which  
it is used or higher, and exhibits excellent retention of the  
shape after a thermal bending even if being left at the  
environmental temperature after the thermal bending, and  
15 particularly, to a fuel feed plastic tube having heat resistance  
to be required for use in, for example, an engine compartment.

### Description of the Related Art

As density of an engine compartment of a motor vehicle  
20 with gears and devices has been advances in recent years, a  
temperature in the engine compartment tends to rise and in some  
case the maximum temperature reaches as high as 150°C. Various  
kinds of tubes used in a motor vehicle are generally arranged  
in position after a thermal bending into required shapes. When  
25 these various kinds of tubes thermally bent accordingly are

exposed to a high temperature, they usually deform and suffer change in the bent shape. On such a change in the bent shape, a plastic tube is brought into contact with a high temperature portion in its neighborhood and thereby strength of the tube  
5 is reduced, which leads to a danger of bursting.

When a plastic tube is exposed to a high temperature for a given period, the tube generally loses its flexibility, and thereby there arises a possibility to cause a noise problem due to vibration during driving of a motor vehicle. Furthermore,  
10 due to change in a bent shape of a tube or increase in stiffness of the tube, when an excessive stress is imposed on a connecting section between a joint and a tube, there arises another possibility to cause a breakage of the joint or the tube.

Change in diametral dimension of a tube dependent on the  
15 temperature in a thermal bending usually unfavorably affects sealing performance in a connecting section and retainability performance in tube's characteristics.

The invention has been made with attention to the above actual circumstances and it is an object of the invention to  
20 provide a heat resistant tube that can be thermally bent at a temperature of the environment in which it is used or higher, and exhibits excellent retention of the resultant bent shape even if being left at the environmental temperature after the thermal bending.

25 It is another object of the invention to provide a thermally

bent tube excellent in heat resistance that exhibits a small change in diameter and retains flexibility.

It is still another object of the invention to provide a tube that exhibits excellent heat resistance and can retain  
5 its thermally bent shape, its dimensions and its flexibility even in a harsh environmental atmosphere, for example, within an engine compartment of a motor vehicle where a maximum temperature reaches as high as 150°C.

#### 10 Summary of the Invention

A heat resistant plastic tube of the invention is substantially made of a polyester-based elastomer and exhibits a change amount in angle of  $\pm 10^\circ$  or less in a shape retainability performance test, a change rate in inner diameter of  $\pm 2\%$  or  
15 less in a dimensional stability performance test, and a change rate in yield strength of  $\pm 30\%$  or less in a flexibility retainability performance test.

A heat resistant plastic tube of the invention has at least an inner layer substantially made of a polyester-based elastomer  
20 and an outer layer formed on an outside of the inner layer and substantially made of a crystalline polyester-based resin, and exhibits a change amount in angle of  $\pm 10^\circ$  or less in a shape retainability performance test, a change rate in inner diameter of  $\pm 2\%$  or less in a dimensional stability performance test,  
25 and a change rate in yield strength of  $\pm 30\%$  in a flexibility

retainability performance test.

A heat resistant plastic tube of the invention has at least an inner layer substantially made of a crystalline polyester-based resin and an outer layer formed on an outside  
5 of the inner layer and substantially made of a polyester-based elastomer, and exhibits a change amount in angle of  $\pm 10^\circ$  or less in a shape retainability performance test, a change rate in inner diameter of  $\pm 2\%$  or less in a dimensional stability performance test, and a change rate in yield strength of  $\pm 30\%$   
10 in a flexibility retainability performance test.

A heat resistant plastic tube of the invention has at least an inner layer made substantially of a polyester-based elastomer, an intermediate layer formed on an outside of the inner layer and substantially made of a crystalline polyester-based resin,  
15 and an outer layer formed on an outside of the intermediate layer and substantially made of a polyester-based elastomer, and exhibits a change amount in angle of  $\pm 10^\circ$  or less in a shape retainability performance test, a change rate in inner diameter of  $\pm 2\%$  in a dimensional stability performance test, and a change  
20 rate in yield strength of  $\pm 30\%$  in a flexibility retainability performance test.

A heat resistant plastic tube of the invention may be used as a fuel feed tube used within an engine compartment of a motor vehicle.

25 A heat resistant plastic tube of the invention may have

a bellows portion at least part of its length.

In a heat resistant plastic tube of the invention, the innermost layer may have a surface resistivity in the range of from  $10^2$  to  $10^9$   $\Omega/\text{sq.}$

5        A manufacturing method of a heat resistant plastic tube of the invention, the tube being provided with a bent portion, includes steps of setting a body of a heat resistant plastic tube in a thermal bending mold, heating the tube body in the mold at  $190^\circ\text{C}$  or higher and cooling the tube body in a state  
10    being set in the mold.

The foregoing and other objects and effects of the invention will become apparent from the following description with reference to the accompanying drawings.

#### 15    Brief Description of the Drawings

Fig. 1 is a perspective view of an example of a heat resistant tube.

Fig. 2 is a perspective view of another example of a heat resistant tube.

20        Fig. 3 is a perspective view of still another example of a heat resistant tube.

Fig. 4 is a perspective view of still another example of a heat resistant tube.

Fig. 5 is a perspective view of still another example of  
25    a heat resistant tube.

Fig. 6 is a plan view showing a thermal bending method of a tube.

Fig. 7 is a front view showing the thermal bending method of a tube.

5 Figs. 8A and 8B show views for an evaluation method of a shape retainability performance of a thermally bent tube.

#### Detailed Description of the Preferred Embodiments

Heat resistant plastic tubes of the present invention can  
10 include the following.

A tube 8, as shown in Fig. 1, is substantially made of a polyester-based elastomer.

A tube 10, as shown in Fig. 2, has at least an inner layer  
11 substantially made of a polyester-based elastomer and an outer  
15 layer 12 formed on an outside of the inner layer 11 and substantially made of a crystalline polyester-based resin.

A tube 20, as shown in Fig. 3, has at least an inner layer  
21 substantially made of a crystalline polyester-based resin and an outer layer 22 formed on an outside of the inner layer  
20 21 and substantially made of a polyester-based elastomer.

A tube 30, as shown in Fig. 4, has at least an inner layer  
31 substantially made of a polyester-based elastomer, an intermediate layer 32 formed on an outside of the inner layer  
31 and substantially made of a crystalline polyester-based  
25 resin, and an outer layer 33 formed on an outside of the

intermediate layer 32 and substantially made of a polyester-based elastomer.

A tube 40 may have one or more bellows portions 41. Fig 5 shows a tube with a plurality of bellow portions 41 spaced apart.

Polyester-based elastomers used in the invention can include, e.g. a polyester-polyether block copolymer, and a polyester-polyester block copolymer.

The polyester-polyether block copolymer has an aromatic polyester as a hard segment component and an aliphatic polyether as a soft segment component, while the polyester-polyester block copolymer has an aromatic polyester as a hard segment component and an aliphatic polyester as a soft segment component, wherein soft segment components and hard segment portions are alternately arranged in a repeated manner so as to construct a block copolymer having a nature of a rubber-like elastic body.

Acids and glycols constructing such polyester hard segments are, respectively, mainly aromatic dicarboxylic acids and alkylene glycols having 2 to 15 carbon atoms.

Dicarboxylic acids include, for example, terephthalic acid, isophthalic acid, ethylenebis(p-oxybenzoic acid), naphthalenedicarboxylic acid, 1,4-cyclohexanedicarboxylic acid, and p-( $\beta$ -hydroxyethoxy)benzoic acid.

Alkylene glycols include, for example, ethylene glycol, propylene glycol, tetramethylene glycol, pentamethylene glycol,

2,2-dimethyltrimethylene glycol, hexamethylene glycol, decamethylene glycol, cyclohexamethylenedimethanol, cyclohexanediethanol, benzenedimethanol, and benzenediethanol.

5           An aliphatic polyether constituting soft segments of the polyester-polyether block copolymer is a polyoxyalkylene glycol having an average molecular weight of the order in the range of from 500 to 5000. The polyoxyalkylene glycol has an oxyalkylene glycol having an alkylene group with 2 to 9 carbon  
10 atoms as a monomer unit.

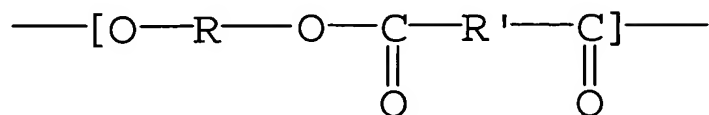
          Preferred examples thereof may be, for example, poly(oxyethylene) glycol, and poly(oxypropylene) glycol, poly(oxytetramethylene) glycol. A polyether may be of a homopolymer, a random copolymer, a block copolymer and a mixture  
15 of two or more kinds of polyethers. A small number of aliphatic groups and aromatic groups may be included in a molecular chain of a polyether. A modified polyethers having, for example, sulfur, nitrogen, and phosphorus may also be used.

          Examples of aliphatic polyesters constituting soft  
20 segments of the polyester-polyester block copolymer includes a condensation type polyester obtained by a dehydration condensation reaction between a dibasic acid and an aliphatic glycol, and a lactone-based polyester obtained by a ring opening polymerization of a lactone represented by  $\gamma$ -butyrolactone,  
25  $\epsilon$ -caprolactone, and two or more kinds of the polyesters may be



used together in a mixture.

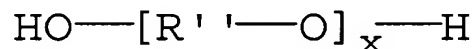
A crystalline polyester used in the invention has the following fundamental structural formula:



5 wherein R indicates a divalent aliphatic group and/or an alicyclic group having a branched chain or a non-branched chain and having 2 to 12 carbon atoms and preferably 2 to 8 carbon atoms in a carbon chain, while R' indicates a divalent aromatic group having 6 to 20 carbon atoms and preferably 8 to 12 carbon  
10 atoms in a carbon skeleton.

Examples of diols include ethylene glycol, trimethylene glycol, tetramethylene glycol, hexamethylene glycol, neopentyl glycol, and cyclohexanedimethanol.

An amount from zero up to 25 mol % of a diol described  
15 above may be replaced with a second diol of the diols already described above or a diol expressed by the following general formula:



wherein R'' indicates a divalent group having 2 to 4 carbon atoms  
20 and x can be an integer from 2 to 50.

Preferably used as a diol are ethylene glycol and tetramethylene glycol.

Aromatic dicarboxylic acids include, for example, terephthalic acid, isophthalic acid,

1,4-naphthalenedicarboxylic acid,  
1,5-naphthalenedicarboxylic acid,  
2,6-naphthalenedicarboxylic acid,  
2,7-naphthalenedicarboxylic acid, diphenic acid and  
5 diphenylether-4,4'-dicarboxylic acid.

An amount from zero up to 20 mol % of the dicarboxylic acid may be replaced with a aliphatic dicarboxylic acid, for example, a succinic acid, maleic acid, fumaric acid, sebacic acid, and dodecanediacid.

10 The following components may be contained in each layer when required as far as heat resistance is not affected unfavorably thereby: other resins, elastomer components, compounds having a functional group for improving an adhesion, which are melt mixed, and various kinds of additive agents  
15 including, for example, an antioxidant, a coloring agent, an antistatic agent, a flame retarder, a reinforcing agent, a stabilizer, a forming auxiliary and a conductive material.

A tube of the invention exhibits a change amount in angle of  $\pm 10^\circ$  or less in a shape retainability performance test, a  
20 change rate in inner diameter of  $\pm 2\%$  or less in a dimensional stability performance test and a change rate in yield strength of  $\pm 30\%$  or less in a flexibility retainability performance test. More preferably, a tube of the invention exhibits a change amount in angle  $\pm 5^\circ$  or less in a shape retainability performance test,  
25 a change rate inner diameter of  $\pm 1\%$  or less in a dimensional

stability performance test and a change rate in yield strength of  $\pm 10\%$  or less in a flexibility retainability performance test. These test methods will be described later.

In case where a change amount in angle in a shape  
5 retainability performance test falls outside the range of  $\pm 10^\circ$ , there arises a fault in that the tube interferes with another member in the neighborhood thereof, and then becomes melted, worn, thereby reduced in strength and injured; in a case where a change rate in inner diameter in a dimensional stability  
10 performance test falls outside the range of  $\pm 2\%$ , there arises a fault that a connecting section between the tube and other member will be less hermitically sealed; and in a case where a change rate in yield strength in a flexibility retainability performance test falls outside the range of  $\pm 30\%$ , there arise  
15 a problem that a vibration from another member cannot be sufficiently absorbed and causes noise and the like.

A heat resistant plastic tube of the invention can be made by molding a resin composition containing components described above. Molding methods, which may be known methods, include,  
20 for example, a method in which components are kneaded and then molded, a method in which components are twin-screw extruded and then molded, and a method in which a tube is molded by means of tube extrusion. A heat resistant plastic tube of a multilayer structure as described above may be molded by means of any of  
25 known molding methods such as co-extrusion molding, extrusion

coating and the like. For example, a tube of a multilayer structure may be efficiently molded by means of co-extrusion molding with plural extruders in number corresponding to required layer structure and a multilayer tube die. A heat tube  
5 with a bellows structure may be obtained by a method using a known corrugator machine, a method in which a tube is molded and then subjected to a thermal molding with a corrugated die or the like in a separate step.

[Examples]

10           The present invention is further described below based on examples. In the examples described below, the following methods are used for evaluation in a shape retainability performance test, a dimensional stability performance test and a flexibility retainability performance test.

15           (1) Thermal bending method

As shown in Figs. 6 and 7, tubes 1 are set in thermal bending molds 2 with an angle of 90°, left in air ovens at temperatures 160°C, 180°C, 190°C and 200°C, respectively, for 30 min and thereafter, taken out therefrom, and immediately  
20 cooled in water for 5 min.

(2) Evaluation methods

(2)-1 Evaluation method of shape retainability  
performance for thermally bent tube

Thermally bent tubes obtained in the foregoing thermal  
25 bending are heat-treated in the air oven at 150°C for 1 hr, then

taken out and immediately cooled in water for 5 min.

As shown in Figs. 8A and 8B, a thermally bent tube A and a 150°C x 1 hr heat-treated tube B are measured on respective angles  $\theta_1$  and  $\theta_2$  to calculate a change amount in angle using the following expression.

A change amount in angle ( $^\circ$ ) = an angle  $\theta_2$  ( $^\circ$ ) of a 150°C x 1 hr heat-treated tube B - (minus) an angle  $\theta_1$  ( $^\circ$ ) of a thermally bent tube A. Also described as the change amount in angle of shape retainability performance test ( $^\circ$ ) including in a thermally bent tube with an angle  $\theta_1$  ( $^\circ$ ), an angle ( $\theta_2$ ) ( $^\circ$ ) after a heat treatment in an air oven at 150°C for 1 hr, followed by an immediate cooling in water for five min being measured, and then a change amount ( $\theta_2^\circ - \theta_1^\circ$ ) being obtained.

(2)-2 Evaluation method of dimensional stability performance

In general, tubes for a motor vehicle are in most of cases used in a state being inserted or pressed into a connecting member, and therefore evaluation of a dimensional stability performance is conducted by measuring a change amount in inner diameter of a tube.

Inner diameter measurement is conducted by inserting a gauge into a tube and measuring a diameter of its end part.

A change rate in inner diameter (%) =  $100 \times$  ( an inner diameter of end part of a tube after the thermal bending or further through the 150°C x 1 hr heat-treatment - an inner diameter

of an unprocessed tube)/the inner diameter of the unprocessed tube. Also described as the a change rate in inner diameter in a dimensional stability performance test (%) including 100 x (an inner diameter of a tube at an end after a thermal bending or further through a 150°C x 1 hr heat treatment - an inner diameter of an unprocessed tube at an end)/the inner diameter of the unprocessed tube at an end.

(3) Evaluation method of flexibility retainability performance

10 Evaluation of a flexibility retainability performance is conducted in a procedure in which a tube is actually subjected to a tensile test and a yield strength is measured.

In yield strength measurement, a tool of SAE J2043 is used to measure a yield strength at a pulling speed of 100 mm/min.

15 A change rate (%) = 100 x ( a yield strength of a thermally bent tube or a 150°C x 240 hr heat-treated tube - a yield strength of an unprocessed tube)/the yield strength of the unprocessed tube. Also described as the change rate in yield strength in a flexibility retainability performance test (%) including 20 100 x (a yield strength of a thermally bent tube or a thermally bent tube with a further 150°C x 240 hr heat treatment - a yield strength of an unprocessed tube)/the yield strength of the unprocessed tube, yield strength being measured by a tool of SAE J2043 at a pulling speed of 100nm/min.

(Example 1)

A single layer tube of 8 mm in outer diameter, 6 mm in inner diameter and 1 mm in thickness was extruded and molded using a polyester-based elastomer of 550 MPa in bending elastic modulus measured by means of the ASTM D790 method.

(Example 2)

A single layer tube of 8 mm in outer diameter, 6 mm in inner diameter and 1 mm in thickness was extruded and molded using a polyester-based elastomer of 160 MPa in bending elastic modulus measured by means of the ASTM D790 method.

(Example 3)

A single layer tube of 8 mm in outer diameter, 6 mm in inner diameter and 1 mm in thickness was extruded and molded using a polyester-based elastomer of 480 MPa in bending elastic modulus measured by means of the ASTM D790 method.

(Example 4)

A single layer tube of 8 mm in outer diameter, 6 mm in inner diameter and 1 mm in thickness was extruded and molded using a polyester-based elastomer of 700 MPa in bending elastic modulus measured by means of the ASTM D790 method.

(Example 5)

A tube of a two layer structure of 8 mm in outer diameter, 6 mm in inner diameter and 1 mm in thickness was obtained by extrusion molding wherein the tube has an inner layer (0.9 mm in thickness) of polyester-based elastomer of 550 MPa in bending

elastic modulus measured by means of the ASTM D790 method and an outer layer (0.1 mm in thickness) of polybutyleneterephthalate resin.

(Example 6)

5           A tube of a two layer structure of 8 mm in outer diameter, 6 mm in inner diameter and 1 mm in thickness was obtained by extrusion molding wherein the tube has an inner layer (0.9 mm in thickness) of polyester-based elastomer of 550 MPa in bending elastic modulus measured by means of the ASTM D790 method and  
10 an outer layer (0.1 mm in thickness) of polybutylenenaphthalate resin.

(Example 7)

By extrusion molding, a tube of a two layer structure of 8 mm in outer diameter, 6 mm in inner diameter and 1 mm in thickness  
15 was obtained wherein the tube has an inner layer (0.1 mm in thickness) of polybutyleneterephthalate resin and an outer layer (0.9 mm in thickness) of polyester-based elastomer of 550 MPa in bending elastic modulus measured by means of the ASTM D790 method.

20 (Example 8)

By extrusion molding, a tube of a two layer structure of 8 mm in outer diameter, 6 mm in inner diameter and 1 mm in thickness was obtained. The tube has an inner layer (0.1 mm in thickness) of polybutylenenaphthalate resin and an outer layer (0.9 mm in  
25 thickness) of polyester-based elastomer of 550 MPa in bending



elastic modulus measured by means of the ASTM D790 method.

(Example 9)

By extrusion molding, a tube of a three layer structure of 8 mm in outer diameter, 6 mm in inner diameter and 1 mm in thickness was obtained. The tube has an inner layer (0.45 mm in thickness) of polyester-based elastomer of 160 MPa in bending elastic modulus measured by means of the ASTM D790 method, an intermediate layer (0.1 mm in thickness) of polybutyleneterephthalate resin and an outer layer (0.45 mm in thickness) of polyester-based elastomer of 550 MPa in bending elastic modulus measured by means of the ASTM D790 method.

(Example 10)

By extrusion molding, a tube of a three layer structure of 8 mm in outer diameter, 6 mm in inner diameter and 1 mm in thickness was obtained. The tube has an inner layer (0.45 mm in thickness) of polyester-based elastomer of 160 MPa in bending elastic modulus measured by means of the ASTM D790 method, an intermediate layer (0.1 mm in thickness) of polybutylenenaphthalate resin and an outer layer (0.45 mm in thickness) of polyester-based elastomer of 550 MPa in bending elastic modulus measured by means of the ASTM D790 method.

(Comparative Example 1)

A single layer tube of 8 mm in outer diameter, 6 mm in inner diameter and 1 mm in thickness was obtained by extrusion molding using an externally plasticized Nylon 11.

(Comparative Example 2)

A single layer tube of 8 mm in outer diameter, 6 mm in inner diameter and 1 mm in thickness was obtained by extrusion molding using an externally plasticized Nylon 12.

5 (Comparative Examples 3 to 13)

Tubes of 8 mm in outer diameter, 6 mm in inner diameter and 1 mm in thickness, having structures shown in tables were obtained by extrusion molding using materials shown in the tables.

10 Thickness values (mm) of layers of Comparative Examples 3 to 13 are as follows:

Comparative Example 3: inner layer/intermediate layer/adhesive layer/outer layer = 0.1/0.1/0.1/0.7

Comparative Example 4: inner layer/adhesive layer/outer layer = 0.45/0.1/0.45

15 Comparative Example 5: inner layer/intermediate layer 1/intermediate layer 2/intermediate layer 3/ outer layer = 0.45/0.15/0.05/0.05/0.30

Comparative Example 6: inner layer/intermediate layer 1/intermediate layer 2/ outer layer = 0.35/0.3/0.1/0.25

20 Comparative Example 7: inner layer/adhesive layer 1/ outer layer = 0.1/0.1/0.8

Comparative Example 8: inner layer/adhesive layer 1/intermediate layer/ adhesive layer 2/outer layer = 0.35/0.1/0.1/0.1/0.35

25 Comparative Example 9: inner layer/adhesive layer/outer

layer = 0.2/0.1/0.7

Comparative Example 10: inner layer/adhesive layer/outer

layer = 0.2/0.1/0.7

Comparative Example 11: inner layer/intermediate

5 layer/outer layer = 0.4/0.2/0.4

Comparative Example 12: inner layer/adhesive layer

1/intermediate layer/ adhesive layer 2/outer layer =

0.3/0.1/0.2/0.1/0.3

Comparative Example 13: inner layer/adhesive layer/outer

10 layer = 0.1/0.1/0.8

Physical properties were measured on the tubes obtained from the foregoing examples and comparative examples. Results of the tests are shown in Tables 1 to 4. Details of abbreviation in the tables are as follows:

15 (inner): tube inner layer

(outer): tube outer layer

PBN: polybutylenenaphthalate resin

PBT: polybutyleneterephthalate resin

PA6: Nylon 6 resin

20 PA6-66: Nylon 6/66 copolymer resin

PA11: Nylon 11 resin

PA12: Nylon 12 resin

EVOH: ethylene-vinyl alcohol copolymer resin

ETFE: ethylene-tetrafluoroethylene copolymer resin

25 PVdF: polyvinylidene fluoride resin

THV:

tetrafluoroethylene-hexafluoropropylene-vinylidene fluoride  
copolymer resin

PPS: polyphenylene sulfide resin

5        A comprehensive evaluation of heat resistant tubes is shown  
in Table 1. In Table 1, evaluation criterion are as follows:

Shape retainability performance: change amount in angle:  
 $\pm 10^\circ$  or less marked with O and outside  $\pm 10^\circ$  marked with X

10       Dimensional stability performance: change rate in inner  
diameter:  $\pm 2\%$  or less marked with O and outside  $\pm 2\%$  marked  
with X

Flexibility retainability performance: change rate in  
yield strength:  $\pm 30\%$  or less marked with O and outside  $\pm 30\%$   
marked with X

15       Furthermore, change amounts in angle (evaluation  
criteria:  $\pm 10^\circ$  or less) are shown in Table 2, change rate in  
inner diameter (evaluation criteria:  $\pm 2\%$  or less) in Table 3  
and change rate in yield strength (evaluation criteria:  $\pm 30\%$   
or less) in Table 4.

[Table 1]

	tube structure	thermal bending temperature (°C) in shape retainability performance				dimensional stability performance	Flexibility retainability performance
		160	180	190	200		
example 1	polyester-based elastomer single layer (bending elastic modulus: 550MPa)	×	×	○	○	○	○
example 2	polyester-based elastomer single layer (bending elastic modulus: 160MPa)	×	×	○	○	○	○
example 3	polyester-based elastomer single layer (bending elastic modulus: 480MPa)	×	×	○	○	○	○
example 4	polyester-based elastomer single layer (bending elastic modulus: 700MPa)	×	×	○	○	○	○
example 5	(inner) polyester-based elastomer (bending elastic modulus: 550 MPa)/PBT (outer)	×	×	○	○	○	○
example 6	(inner) polyester-based elastomer (bending elastic modulus: 550 MPa)/PBN (outer)	×	×	○	○	○	○
example 7	(inner) PBT/polyester-based elastomer (bending elastic modulus: 550 MPa) (outer)	×	×	○	○	○	○
example 8	(inner) PBN/polyester-based elastomer (bending elastic modulus: 550 MPa) (outer)	×	×	○	○	○	○
example 9	(inner) polyester-based elastomer (bending elastic modulus: 160 MPa)/PBT/polyester-based elastomer (bending elastic modulus: 550 MPa)	×	×	○	○	○	○
example 10	(inner) polyester-based elastomer (bending elastic modulus: 160 MPa)/PBT/polyester-based elastomer (bending elastic modulus: 550 MPa)	×	×	○	○	○	○
comparative example 1	Externally plasticized PA11	○	deformed	melted	melted	×	×
comparative example 2	Externally plasticized PA12	○	melted	melted	melted	×	×
comparative example 3	(inner) conductive ETFE/ETFE/adhesive resin/PA12 (outer)	○	melted	melted	melted	×	×
comparative example 4	(inner)PA6/adhesive resin/PA12 (outer)	○	melted	melted	melted	×	×
comparative example 5	(inner) PA6/EVOH/PA6/modified polyolefin/PA12 (outer)	○	melted	melted	melted	×	×
comparative example 6	(inner) PA6/PA6-66/modified polyolefin/PA12 (outer)	○	melted	melted	melted	×	×
comparative example 7	(inner)PBT/adhesive resin/PA12 (outer)	○	melted	melted	melted	×	×
comparative example 8	(inner) PA12/adhesive resin/PBT/adhesive resin/PA12 (outer)	○	melted	melted	melted	×	×
comparative example 9	(inner)THV/adhesive resin/PA12 (outer)	○	melted	melted	melted	×	×
comparative example 10	(inner)PVdF/adhesive resin/PA12 (outer)	○	melted	melted	melted	×	×
comparative example 11	(inner)PA12/PVdF/PA12 (outer)	○	melted	melted	melted	×	×
comparative example 12	(inner) PA12/adhesive resin/PVdF/adhesive resin/PA12 (outer)	○	melted	melted	melted	×	×
comparative example 13	(inner)PPS/adhesive resin/PA12 (outer)	○	melted	melted	melted	×	×

[Table 2]

	tube structure	thermal bending (160°C × 30 min)	Thermal bending (180°C × 30 min)	thermal bending (190°C × 30 min)	Thermal bending (200°C × 30 min)
		after heat treatment (150°C × 1 hr) of thermally bent tube	after heat treatment (150°C × 1 hr) of thermally bent tube	after heat treatment (150°C × 1 hr) of thermally bent tube	after heat treatment (150°C × 1 hr) of thermally bent tube
example 1	polyester-based elastomer single layer (bending elastic modulus: 550MPa)	×	×	○	◎
example 2	polyester-based elastomer single layer (bending elastic modulus: 160MPa)	×	×	○	◎
example 3	polyester-based elastomer single layer (bending elastic modulus: 480MPa)	×	×	○	◎
example 4	polyester-based elastomer single layer (bending elastic modulus: 700MPa)	×	×	○	◎
example 5	(inner) polyester-based elastomer (bending elastic modulus: 550 MPa)/PBT (outer)	×	×	○	◎
example 6	(inner) polyester-based elastomer (bending elastic modulus: 550 MPa)/PBN (outer)	×	×	○	◎
example 7	(inner) PBT/polyester-based elastomer (bending elastic modulus: 550 MPa) (outer)	×	×	○	◎
example 8	(inner) PBN/polyester-based elastomer (bending elastic modulus: 550 MPa) (outer)	×	×	○	◎
example 9	(inner) polyester-based elastomer (bending elastic modulus: 160 MPa)/PBT/polyester-based elastomer (bending elastic modulus: 550 MPa)	×	×	○	◎
example 10	(inner) polyester-based elastomer (bending elastic modulus: 160 MPa)/PBT/polyester-based elastomer (bending elastic modulus: 550 MPa)	×	×	○	◎
comparative example 1	Externally plasticized PA11	×	○	deformed	Melted
comparative example 2	Externally plasticized PA12	×	○	melted	Melted
comparative example 3	(inner) conductive ETFE/ETFE/adhesive resin/PA12 (outer)	×	○	melted	Melted
comparative example 4	(inner)PA6/adhesive resin/PA12 (outer)	×	○	melted	Melted
comparative example 5	(inner) PA6/EVOH/PA6/modified polyolefin/PA12 (outer)	×	○	melted	Melted
comparative example 6	(inner) PA6/PA6-66/modified polyolefin/PA12 (outer)	×	○	melted	Melted
comparative example 7	(inner)PBT/adhesive resin/PA12 (outer)	×	○	melted	Melted
comparative example 8	(inner) PA12/adhesive resin/PBT/adhesive resin/PA12 (outer)	×	○	melted	Melted
comparative example 9	(inner)THV/adhesive resin/PA12 (outer)	×	○	melted	Melted
comparative example 10	(inner)PVdF/adhesive resin/PA12 (outer)	×	○	melted	Melted
comparative example 11	(inner)PA12/PVdF/PA12 (outer)	×	○	melted	Melted
comparative example 12	(inner) PA12/adhesive resin/PVdF/adhesive resin/PA12 (outer)	×	○	melted	Melted
comparative example 13	(inner)PPS/adhesive resin/PA12 (outer)	×	○	melted	Melted

◎: ± 5° or less, ○: range from ±5° to ±10°, ×: outside ± 10°

[Table 3]

	tube structure	change percentage in inner diameter					
		after thermal bending at 160°C × 30 min	after heat treatment at 150°C × 1 hr of thermally bent tube	after thermal bending at 180°C × 30 min	after heat treatment at 150°C × 1 hr of thermally bent tube	after thermal bending at 200°C × 30 min	after heat treatment at 150°C × 1 hr of thermally bent tube
example 1	polyester-based elastomer single layer (bending elastic modulus: 550MPa)	⊙	⊙	⊙	⊙	⊙	⊙
example 2	polyester-based elastomer single layer (bending elastic modulus: 160MPa)	⊙	⊙	⊙	⊙	⊙	⊙
example 3	polyester-based elastomer single layer (bending elastic modulus: 480MPa)	⊙	⊙	⊙	⊙	⊙	⊙
example 4	polyester-based elastomer single layer (bending elastic modulus: 700MPa)	⊙	⊙	⊙	⊙	⊙	⊙
example 5	(inner) polyester-based elastomer (bending elastic modulus: 550 MPa)/PBT (outer)	⊙	⊙	⊙	⊙	⊙	⊙
example 6	(inner) polyester-based elastomer (bending elastic modulus: 550 MPa)/PBN (outer)	⊙	⊙	⊙	⊙	⊙	⊙
example 7	(inner) PBT/polyester-based elastomer (bending elastic modulus: 550 MPa) (outer)	⊙	⊙	⊙	⊙	⊙	⊙
example 8	(inner) PBN/polyester-based elastomer (bending elastic modulus: 550 MPa) (outer)	⊙	⊙	⊙	⊙	⊙	⊙
example 9	(inner) polyester-based elastomer (bending elastic modulus: 160 MPa)/PBT/polyester-based elastomer (bending elastic modulus: 550 MPa)	⊙	⊙	⊙	⊙	⊙	⊙
example 10	(inner) polyester-based elastomer (bending elastic modulus: 160 MPa)/PBT/polyester-based elastomer (bending elastic modulus: 550 MPa)	⊙	⊙	⊙	⊙	⊙	⊙
comparative example 1	externally plasticized PA11	○	×	×	×	-	-
comparative example 2	externally plasticized PA12	○	×	-	-	-	-
comparative example 3	(inner) conductive ETFE/ETFE/adhesive resin/PA12 (outer)	○	×	-	-	-	-
comparative example 4	(inner) PA6/adhesive resin/PA12 (outer)	○	×	-	-	-	-
comparative example 5	(inner) PA6/EVOH/PA6/modified polyolefin/PA12 (outer)	○	×	-	-	-	-
comparative example 6	(inner) PA6/PA6-66/modified polyolefin/PA12 (outer)	○	×	-	-	-	-
comparative example 7	(inner) PBT/adhesive resin/PA12 (outer)	○	×	-	-	-	-
comparative example 8	(inner) PA12/adhesive resin/PBT/adhesive resin/PA12 (outer)	○	×	-	-	-	-
comparative example 9	(inner) THV/adhesive resin/PA12 (outer)	○	×	-	-	-	-
comparative example 10	(inner) PVdF/adhesive resin/PA12 (outer)	○	×	-	-	-	-
comparative example 11	(inner) PA12/PVdF/PA12 (outer)	○	×	-	-	-	-
comparative example 12	(inner) PA12/adhesive resin/PVdF/adhesive resin/PA12 (outer)	○	×	-	-	-	-
comparative example 13	(inner) PPS/adhesive resin/PA12 (outer)	○	×	-	-	-	-

⊙: ± 1% or less, ○: range between ±1% to ±2%, ×: outside ± 2%

[Table 4]

	tube structure	Change percentage in yield strength					
		After thermal bending at 160°C x 30 min	After heat treatment at 150°C x 240 hr of thermally bent tube	after thermal bending at 180°C x 30 min	after heat treatment at 150°C x 240 hr of thermally bent tube	after thermal bending at 200°C x 30 min	after heat treatment at 150°C x 240 hr of thermally bent tube
example 1	polyester-based elastomer single layer (bending elastic modulus: 550MPa)	⊙	○	⊙	○	⊙	○
example 2	polyester-based elastomer single layer (bending elastic modulus: 160MPa)	○	○	○	○	○	○
example 3	polyester-based elastomer single layer (bending elastic modulus: 480MPa)	⊙	○	⊙	○	⊙	○
example 4	polyester-based elastomer single layer (bending elastic modulus: 700MPa)	⊙	○	⊙	○	⊙	○
example 5	(inner) polyester-based elastomer (bending elastic modulus: 550 MPa)/PBT (outer)	⊙	○	⊙	○	⊙	○
example 6	(inner) polyester-based elastomer (bending elastic modulus: 550 MPa)/PBN (outer)	⊙	○	⊙	○	⊙	○
example 7	(inner) PBT/polyester-based elastomer (bending elastic modulus: 550 MPa) (outer)	⊙	○	⊙	○	⊙	○
example 8	(inner) PBN/polyester-based elastomer (bending elastic modulus: 550 MPa) (outer)	⊙	○	⊙	○	⊙	○
example 9	(inner) polyester-based elastomer (bending elastic modulus: 160 MPa)/PBT/polyester-based elastomer (bending elastic modulus: 550 MPa)	⊙	○	⊙	○	⊙	○
example 10	(inner) polyester-based elastomer (bending elastic modulus: 160 MPa)/PBT/polyester-based elastomer (bending elastic modulus: 550 MPa)	⊙	○	⊙	○	⊙	○
comparative example 1	externally plasticized PA11	○	×	○	×	×	-
comparative example 2	externally plasticized PA12	○	×	-	-	-	-
comparative example 3	(inner) conductive ETFE /ETFE/adhesive resin/PA12 (outer)	⊙	×	-	-	-	-
comparative example 4	(inner) PA6/adhesive resin/PA12 (outer)	○	×	-	-	-	-
comparative example 5	(inner) PA6/EVOH/PA6/modified polyolefin/PA12 (outer)	○	×	-	-	-	-
comparative example 6	(inner) PA6/PA6-66/modified polyolefin/PA12 (outer)	⊙	×	-	-	-	-
comparative example 7	(inner)PBT/adhesive resin/PA12 (outer)	○	×	-	-	-	-
comparative example 8	(inner) PA12/adhesive resin /PBT/adhesive resin/PA12 (outer)	○	×	-	-	-	-
comparative example 9	(inner)THV/adhesive resin/PA12 (outer)	⊙	×	-	-	-	-
comparative example 10	(inner) PVdF/adhesive resin/PA12 (outer)	○	×	-	-	-	-
comparative example 11	(inner) PA12/PVdF/PA12 (outer)	○	×	-	-	-	-
comparative example 12	(inner) PA12/adhesive resin/PVdF/adhesive resin/PA12 (outer)	○	×	-	-	-	-
comparative example 13	(inner) PPS/adhesive resin/PA12 (outer)	⊙	×	-	-	-	-

⊙: ± 10% or less, ○: range from ±10% to ±30%, ×: outside ± 30%



A heat resistant plastic tube of the invention can be thermally bent at a temperature in a use environment or higher and exhibits excellent retention in bent shape even after standing at the temperature in the use environment after the thermal bending. A recovery in a bent shape is low, a change in dimension is low and flexibility can be retainable. Thermal bending is possible at a temperature of 180°C or higher, preferably 190°C or higher and more preferably 200°C or higher. When a tube is heat treated in an atmosphere at 150°C for 1 hr after the thermal bending, a recovery in a bent shape is  $\pm 10^\circ$  or less and a change in inner diameter is  $\pm 2\%$  or less. When a tube is heat treated in an atmosphere at 150°C for 240 hr after thermal bending, a change rate in yield strength is  $\pm 30\%$  or less. Since structural materials of a multilayer tube of the present invention are all polyester-based materials, materials are re-usable. Since incineration disposal of the tube is possible, no toxic gas including NO<sub>x</sub>, SO<sub>x</sub> and halogen is generated, and the tube is very friendly to environment. The tube of the present invention enables light and compact piping in which strength and flexibility are balanced.